Treatment of losses in Frontier Snowy Regional Boundary change analysis

TECHNICAL ADVICE PAPER PREPARED FOR THE AEMC

Intelligent Energy Systems (IES) recently published an article[1] commenting on the treatment of losses in Frontier Economics' (Frontier's) modelling for the Australian Energy Market Commission (AEMC or Commission) in relation to the Snowy boundary change and congestion management options. The Commission requested Frontier to provide it with technical advice on the issues raised in the IES article. This note seeks to provide that advice by:

- summarising the issues raised by IES;
- discussing Frontier's approach to modelling losses; and
- commenting on the validity of IES's conclusions and their implications (if any) for the modelling undertaken for the Commission.

In summary, Frontier agrees with IES's observation that the modelling results based on SRMC bidding appear counter-intuitive and may be distorted by over- or under-estimation of transmission losses. Frontier's short-run marginal cost (SRMC) bidding analysis shows aggregate losses under the Abolition case are lower compared to aggregate losses under the other cases. This confirms that there is a likely under-estimation of losses in this case, but does not help to explain the source of the under-estimation. Further, the modelling results confirm that under-estimation is not an issue for the game-theoretic strategic bidding analysis, where the results indicate aggregate losses at similar levels across all cases.

In Frontier's view, IES's explanation for these outcomes is misconceived. In particular, Frontier believes that the simple example used in the IES article provides an inappropriate and misleading basis for evaluating the approach used to model the different cases. Rather, Frontier considers that the principal reason for the potential distortion of the SRMC results is that the loss factors provided by NEMMCO and used in the modelling analysis were based on historical generator bidding patterns and power flows. Given that losses are a function of the pattern of flows across the power system, it is understandable that the use of loss factors designed to approximate losses in the real world in a model based on (unrealistic) SRMC bidding is likely to lead to such distortions. However, the use of these loss factors in strategic modelling – which is intended to reflect more realistic bidding behaviour – is far less likely to give rise to similar issues. Indeed, the use of loss factors derived from flows arising from SRMC generator bidding would be likely to produce distorted results if used in conjunction with more realistic bidding assumptions. Therefore, Frontier does not consider that the

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1 IES, "Transmission System Capability and the Decision to Abolish the Snowy Region", Andrew Campbell, Stephen Wallace and Stuart Thorncraft, Insider, Issue 008, 9 October 2007 (IES article), available at http://www.iesys.com.au/DNN/Portals/0/Downloads/Insider%20008.pdf

potential issues affecting the SRMC results would compromise the strategic modelling results, which, in Frontier's view, provide a more relevant basis for the Commission's decision.

SUMMARY OF IES CRITIQUE

The comments in the IES article focussed on Frontier's modelling results produced under the assumption of SRMC generator bidding behaviour. The annual production cost savings arising under this assumption relative to the Base scenario are reproduced in Table 1 below. In all years, the Snowy Hydro Abolition of the Snowy Region (Abolition) scenario resulted in the largest cost savings, followed by the Macquarie Generation Split Snowy Region (SSR) and Southern Generators' Congestion Pricing (SG) scenarios.

Financial year	Abolition ($m)	SSR ($m)	SG ($m)
2008	$1.35	$0.66	-$0.01
2009	$0.99	$0.57	-$0.01
2010	$1.40	$0.89	$0.09

Table 1: Production cost savings relative to the Base scenario under SRMC bidding

IES argued that under the assumption of SRMC bidding, one would expect a representation of the network that contains more regions to be at least as efficient as one that contains fewer regions. This hypothesis is contrary to the results from Frontier's analysis, where the Abolition scenario (which comprises the least number of regions) resulted in the highest production cost savings, implying a more efficient outcome.

IES derived its criticism of the SRMC modelling results based on the following three propositions:

1. The physical system does not change between the boundary change cases;
2. Dispatch based on a pricing/settlement model that amalgamates regions has to result in an equivalent or less efficient model for the physical transmission system than a model with more regions; and
3. Dispatch based on a pricing/settlement model that amalgamates regions has to result in a less efficient model for losses than a model with more regions.

IES presented two possible hypotheses for the divergence in cost outcomes between their hypothesis and the SRMC modelling results:

First, that:

> "The generic constraints supplied by NEMMCO for the modelling are either not equally efficient at utilizing the actual physical network or they do not provide equal levels of security."[2]

IES concluded that this should not be the case because the SSR scenario constraints can always be made at least as efficient at managing physical network capability as the Abolition scenario constraints.

Second, and considered by IES as the more likely cause of the divergence, the greater dispatch efficiency associated with the Abolition scenario was due to an *underestimation* of physical losses in this scenario. Specifically, IES stated that losses between Murray and Victoria and between Tumut and NSW needed to be treated as intra-regional losses in the Abolition scenario, and, as such, should have been "added to" the Victorian and NSW demands. IES stated that not doing this could explain the favourable (lower cost) results obtained for the Abolition case.

To explain this, IES provided a simple example (reproduced below in Figure 1) to illustrate the intuition behind the second hypothesis. The simple example considered the treatment of losses on a network element under a single region model compared to a two-region model where the region boundary crosses the network element in question.

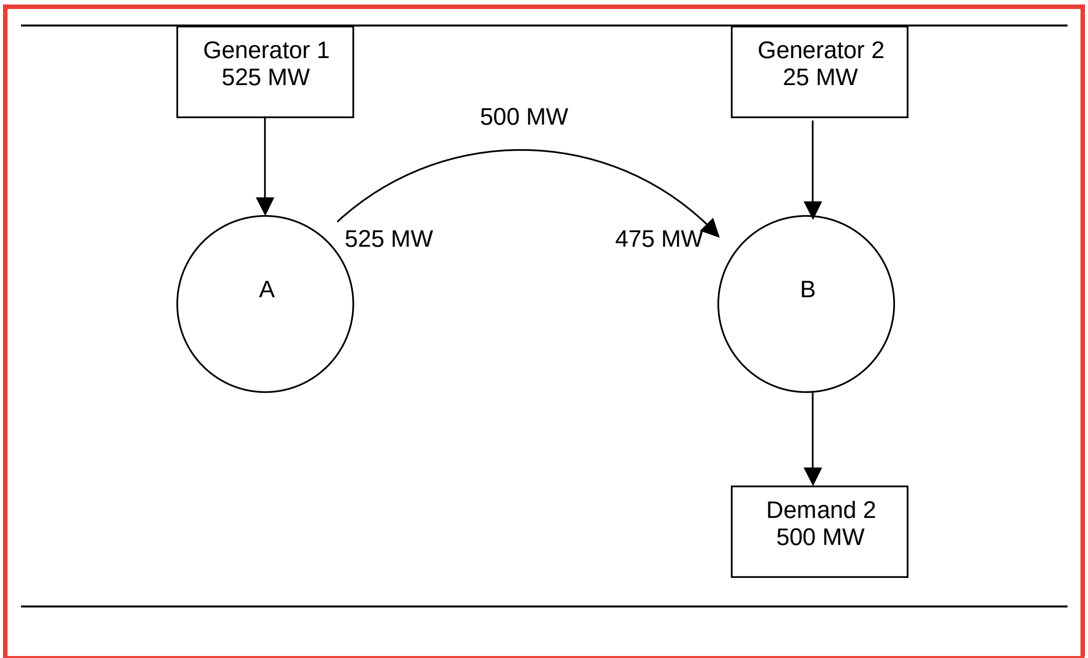

Figure 1: IES example – dispatch and losses

Source: IES article, Figure 1, p.7.

[22] IES article, p.7.

In this example, losses on the line are 50 MW. IES suggested that under a single region model, the losses on the line would be treated as intra-regional losses and hence would be added to regional demand in dispatching the market. Conversely, under a two-region model, these losses would be inter-regional losses and would not be added to demand. Rather, these losses would be accounted for by the interconnector dynamic loss equation. Therefore, to ensure consistency between the modelling of the two regional boundary structures, it would be necessary to "add back" demand equivalent to 50 MW of losses in the one region case. Consequently, if the same level of demand were used to model both the one- and two-region cases, dispatch costs would be artificially lower in the one-region case because aggregate demand plus losses in that region would be 50 MW lower than it should.

IES stated, therefore, that if the same demand forecasts were used under both the Abolition and SSR scenarios without adjustment for losses, the dispatch costs under the SSR scenario would be biased towards a relatively higher cost. This is because the SSR scenario involves more regions and notional interconnectors than the Abolition scenario, and if losses were not properly transformed between models, the SSR model may presume higher losses than others.

IES concluded that with SRMC bidding, both the SSR scenario and the SG scenario should deliver no less production cost savings than the Abolition scenario given both these cases have more regions than the Abolition scenario. That the SRMC results do not conform to this expectation is the basis for IES's criticism of the modelling. IES also inferred that the strategic (game theoretic-based) modelling results may be biased in the same manner as the SRMC results, noting that the measured benefits under the strategic bidding assumptions were of a similar order of magnitude to the SRMC results.

RESPONSE TO IES'S COMMENTS

Frontier agrees that the SRMC modelling results presented in the Commission's Rule determination may appear to be counter-intuitive. In particular, if one assumes that the pattern of dispatch (and hence flows) on the physical network are reasonably consistent between the different cases under SRMC bidding, it follows that aggregate losses, as approximated under each case, should also be reasonably similar. Further, given that the analysis assumed the same demand levels between the cases (ie intra-regional losses were assumed unchanged), one would expect to see very similar production cost outcomes under all the Snowy region scenarios. However, as Table 1 above shows, production costs were lowest in the Abolition scenario and highest in the Base and SG scenarios. This suggests that transmission losses may be *under*-estimated in the Abolition scenario relative to the other cases under SRMC bidding assumptions. Frontier has interrogated the modelling results with respect to aggregate losses and can confirm that losses under the Abolition case are lower than losses under the other cases for SRMC bidding. However, this is not the case for the strategic bidding analysis, which produces consistent levels of aggregate losses across all cases. Interrogation of the modelling results can confirm that there may be an underestimation, but it cannot help to explain the cause of this. We discuss more likely causes later in this note.

Frontier notes that given the marginal difference between all the SRMC results, the possible under- or over- estimation of transmission losses may explain the counter-intuitive nature of the SRMC results.

That being said, Frontier does not agree with the reasoning put forward by IES with respect to the cause for the under-estimation of losses under the Abolition SRMC scenario. The reason for Frontier's position is explained in the following sections. However, the implication of Frontier's position is that we do not consider that the strategic modelling results were compromised by the under-estimation affecting the SRMC results.

Efficiency of loss equations

Frontier acknowledges and agrees with IES's first material point – that the physical system does not alter between the various regional structure scenarios. However, Frontier does not consider that the second and third propositions present compelling explanations for the marginal variation in the SRMC results, nor for the follow-on implications for the strategic results.

A model with more regions would, in general, result in an equivalent or more *accurate* approximation of system losses than a model with fewer regions. A model with more regions would necessarily have more notional interconnectors, and hence could allow for a more accurate set of dynamic loss equations as additional flow variables are available for the loss equation regression. That said, greater accuracy in the loss approximation does not guarantee greater economic efficiency. The economic efficiency implications of a more accurate loss approximation depend on whether and how the increased accuracy results in a change in the pattern of dispatch, and further, a change in total production costs.

Understanding IES's example

The IES example considered an initial case of a single region with no interconnectors, in which all losses are (by definition) purely intra-regional. IES's alternative case involved splitting this single region in two, creating an interconnector, and therefore, measuring explicitly what were formerly intra-regional losses now as inter-regional losses.

From the example, IES suggests that Frontier may not have adjusted NSW and/or Victorian demands to adequately reflect the intra-regional losses in the amended NSW and Victorian regions, previously reflected in inter-regional losses between those and the Snowy regions. This, IES stated, may lead to an under-estimation of production costs in the Abolition scenario, and therefore, an over-estimation of production cost savings.

To consider this reasoning, it is necessary to explain how losses are treated both in the NEM dispatch engine (NEMDE) as well as in the modelling undertaken by Frontier.

Treatment of losses in the NEM

In the physical power system, losses occur on every line according to a range of technical parameters, but broadly proportional to the square of the current flow through the line. The physical power system is approximated within NEMDE, the model that NEMMCO uses to dispatch the market. NEMMCO models losses externally from NEMDE and in advance of dispatch. These losses are provided to NEMDE as an input to dispatch. Frontier's dispatch model, SPARK, integrates losses in a similar manner to NEMDE. For the sake of exposition, the losses included in both NEMDE and the Frontier modelling can be categorised as either inter- or intra-regional losses:

- **Intra-regional losses** – are losses on transmission elements within a region *not related to inter-regional power transfers*, and are a component of the regional demand measure used in the dispatch process. For example, if customer demand in a region is 1,000 MW and intra-regional losses are 50 MW, the aggregate demand for that region used in the dispatch process is 1,050 MW. In the NEM, the dispatch process is performed ex-ante for the upcoming 5-minute dispatch period, hence both customer demand and applicable intra-regional losses must be forecast by NEMMCO ahead of time to feed into the dispatch process. Errors in the forecasts are inevitable, and actual differences between forecast and actual demand (which includes applicable intra-regional losses) are handled by the ancillary services arrangements;
- **Inter-regional losses** – are losses associated with power transfers from one regional reference node (RRN) to another and are treated explicitly in the dispatch process by way of dynamic loss equations for each interconnector. The losses represented by the equation include the losses incurred on all transmission elements between RRNs, including those commonly regarded as "intra-regional" elements. The loss equations are an approximation of the actual physical losses, and are determined by NEMMCO using regression analyses based on forward-looking forecasts of network flows and losses. The accuracy of the loss equations is therefore dependent on both how well actual network flows match the forecasts NEMMCO uses to determine the equations, as well as how well the regression variables fit the data. NEMMCO's forward-looking loss factor methodology is based on historical patterns of generator operation adjusted for committed new projects, and forecasts of connection point load.

The key implications of the loss model employed by NEMMCO in dispatch of the NEM are that:

- Intra-regional losses exclude losses associated with power transfers between regions and are included in the demand measure used in dispatch;
- Inter-regional losses are explicitly approximated using dynamic loss equations and reflect losses arising between RRNs (i.e. not just losses on the network element/s that literally cross the regional boundary);
- The dynamic loss equations are determined on a forward-looking basis based on forecasts of flow patterns – hence the accuracy of these equations depends on how well actual flows match the forecast flows; and

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- The dynamic loss equations are further approximated by regression analysis to determine losses as a function of interconnector flows and regional demand levels.

Modelling of losses and demand for the Snowy options

Treatment of losses

The treatment of losses under the various Snowy region proposals can be illustrated by a stylised representation of the Victoria to NSW flowpath as shown in Figure 2 below. The figure represents the underlying physical network as the thin black lines connecting the blue nodes labelled N for NSW (Sydney West 330), T for Tumut (Lower Tumut 330), M for Murray (Murray 330), D for Dederang (Dederang 330) and V for Victoria (Thomastown 66). The RRNs for each case are shaded in solid blue with a bold outline and region boundaries are shown as the green dotted lines. The thick red arrowed lines indicate notional interconnectors under each case joining the applicable two RRNs.

As noted above, the loss equation for a notional interconnector will approximate the losses on all physical network elements between the associated RRNs. For example, consider an increment of demand in NSW being met by additional generation from Victoria. In the physical network, this would cause additional flows across all shown network elements (the thin black lines). Under the Base scenario, the additional losses on the physical lines between V and M would be reflected in the loss equation for the V-M notional interconnector. Likewise, the additional losses on the physical lines between M and N would be reflected in the loss equation for the M-N notional interconnector. Under the Abolition scenario, the additional losses for all physical lines would be reflected in the loss equation for the V-N notional interconnector, and under the SSR scenario the physical losses would be reflected in the loss equations for the three notional interconnects. Consequently, in all cases, the loss equations capture additional losses on all of the physical lines between the V and N nodes.

However, as noted above, the *accuracy* of the loss equations will differ between the cases, with more notional interconnectors (or more regions) in general delivering greater accuracy. At the same time, a less accurate equation should not *systematically* under- or over-estimate the magnitude of actual losses: a less accurate equation may produce a greater degree of under- or over-estimation at different times depending on the exact system conditions, but should on average produce similar outcomes to a more accurate equation.

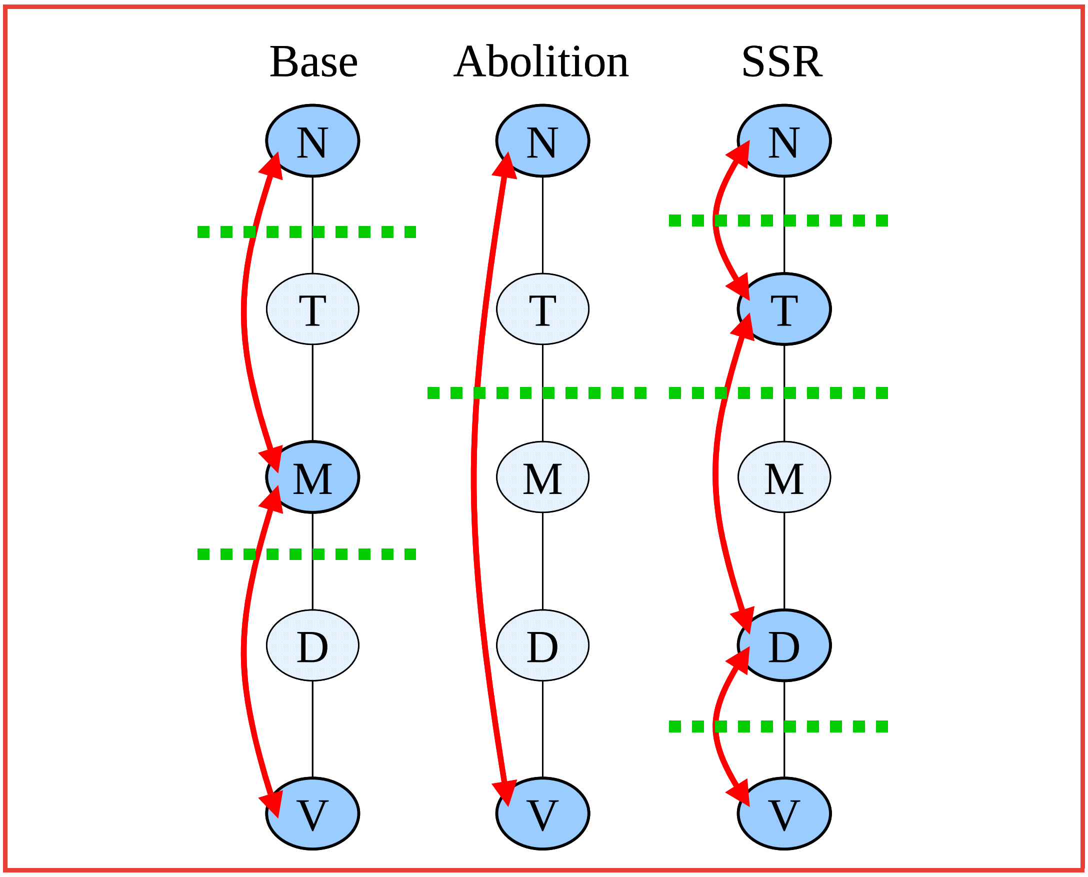

Figure 2: Notional interconnectors for each boundary change option

Therefore, all of these cases modelled by Frontier included a dynamic loss treatment along the *entire* flow path between the Victorian RRN at Thomastown and the NSW RRN at Sydney West. For example, in the Abolition scenario, losses between Thomastown and Sydney West were captured by the loss equation representing the Vic-NSW interconnector. In the Base and SGs scenarios, losses were captured by the loss equations representing the Vic-Snowy and Snowy-NSW interconnectors. Finally, in the SSR scenario, losses between Thomastown and Sydney West were captured by the loss equations representing the Vic-Murray, Murray-Tumut and Tumut-NSW interconnectors. As such, losses on the notional interconnector(s) between Thomastown and Sydney West are *already* accounted for within the dynamic loss equations for the various interconnectors under each case.

In the IES example, under the single region model, no flows between any two points in that region could be represented by an interconnector loss equation. This suggests that the example IES used is not directly comparable to the regional structure around the Snowy region. An example that involved either splitting or abolishing a region containing negligible demand that already had notional interconnectors connecting adjacent regions on both sides would do away with the problems raised by IES. This is because under this alternative example, losses within the region would be consistently treated as inter-regional losses and accounted for by dynamic loss equations under both cases. There would be no need to re-classify any losses as intra-regional in nature.

Treatment of demand

In general, a region change will require the demand associated with network nodes affected by the region change to be reallocated according to the new regional structure. For example, if splitting a single region into two, the demand for the single region would need to be allocated between the two new regions in accordance with the demands for the allocated nodes.

In the particular case of the Snowy region change options, the allocation of demand between the relevant regions is not a material issue. The existing Snowy region has negligible demand (ignoring pumping load), such that there was no demand that needed to be re-allocated. The modelling assumed no demand, and therefore no intra-regional losses, in the Snowy region under the Base scenario, which equates to no change in regional demand under each of the alternative scenarios.

Further, as per the discussion above on the treatment of losses, the loss equation/s for the notional interconnector/s between the Victorian and NSW RRNs under all boundary change cases account for losses on all physical lines between Thomastown and Sydney West with respect to power transfers between the two regions. Hence, an adjustment to demand for any change in intra-regional losses was not considered appropriate.

For all of these reasons, Frontier does not consider that there is an error in the representation of losses and regional demands in the modelling of the different Snowy region scenarios with respect to the treatment of demand or intra-regional losses.

Alternative explanation for SRMC modelling results

As discussed above, Frontier notes that it is plausible that the production cost savings for the Abolition scenario under SRMC bidding are over-estimated due to the under-estimation of losses.

However, in Frontier's view, an alternative and more likely explanation for the over-estimation of cost savings in the Abolition scenario is that the dynamic loss equations that were sourced from NEMMCO and used in the modelling were based on a different pattern of dispatch and therefore, of network flows, than would arise in an artificial world of SRMC generator bidding. NEMMCO's loss equations are based on *historic* patterns of generation and flows adjusted for expected future changes to supply and demand. These historic patterns of generation and flows are in turn based on *historic* generator bidding patterns. As noted above, the accuracy of the dynamic loss equations depends on how well actual network flows within each region match the forecast flows used to derive the equations. The pattern of flows and the corresponding loss outcomes used to derive the NEMMCO dynamic loss equations would therefore not necessarily be consistent with the pattern of generation and flows – and hence losses – likely to occur under SRMC generator bidding. As a result, the use of the NEMMCO loss equations to model the implications of SRMC bidding may have led to the under- or over-estimation of actual losses under those bidding assumptions.

Conversely, under strategic bidding assumptions, Frontier notes that level of losses arising in the modelling was far more consistent between the various cases. In Frontier's view, this is because the strategic bidding analysis, unlike the SRMC analysis, is oriented to producing generation and flow patterns consistent with likely *actual* bidding behaviour. Given that NEMMCO's loss equations were developed largely on the basis of actual historic bidding and dispatch, it follows that the loss equations are more likely to yield accurate results when applied in dispatch modelling that uses strategic bidding assumptions than when used in modelling based on (unrealistic) SRMC bidding. This suggests that the strategic modelling results are not as likely to reflect a bias for under- or over-estimating losses as the SRMC results.

Indeed, if the loss equations used in the strategic modelling were based on SRMC bidding assumptions – which may have addressed the problem with the SRMC results – it is likely that those same equations would have produced distorted results when used alongside more realistic strategic bidding assumptions. Accordingly, it is reasonable to conclude that the issues associated with loss treatment and accuracy are largely isolated to the less realistic SRMC bidding scenarios.